Planning/Grasping/Shelf Subsystem Descriptions

Planning System

Planning for the system will be validated through the SBPL planner and Rviz. Two primary planners will be employed: EGWA* and RRT Connector. RRT Connector is weak within enclosed places bust robust in open environments, and will only be used for out-of-bin planning (such as when moving an item from a bin to a tote). EGWA* is experience-graph-weighted-A*, and will be used for in-bin planning. This planner works by caching successful trajectories for in-bin planning based off of Weighted A* (this may be used for out of bin as well depending on system testing). Once cached, these plans take substantially less processing time, and are “guaranteed” in a sense if they have been validated by hand before being cached.

Planning Scene

The planning scene will be used to verify hardware designs before construction. This will include appropriate placing of bins and any obstructing hardware, as well as arm positioning and mounting. Successfully having the arm demonstrate that it can plan for a grasp and other movements within Rviz is critical to the project success, and will save valuable time and resources when fabricating system components.

As a reach goal for the project the planning scene may also populate itself with object models as they are discovered by the vision system. This would allow the planner to have a more robust behavior when grasping items, as it could avoid unintentionally moving unwanted items within the bin (knocking items from the bin is a real concern and occurred several times with the top teams last year).

Planning Controls

The planner will act in conjunction with other ROS nodes in order to control all DOF for the system, including the linear slide rail and any actuators on the grasper. It is imperative that these actuators are giving precise feedback of their positioning to the system in order to allow for accurate planning (inaccurate feedback could result in collisions with actual system components as a worst-case scenario).

Grasping System

Grasping items can be broken down into two categories: deformables and rigid objects (non-deformables). For deformable items the 6-DOF pose will not be available. Instead the vision system will do what it can to compute the centroid of the deformable item's point cloud, and then it will pass this centroid to grasping. Grasping will then request that the planner attempt to move the gripper directly above the computed centroid, as seen in Figure 1.

As an added security it may be worth considering a way for Grasping to determine backup grasp points in the case that the centroid grasp point is unavailable via the current planning scene (likely this would be a matter of determining what points closest to the centroid would be available).

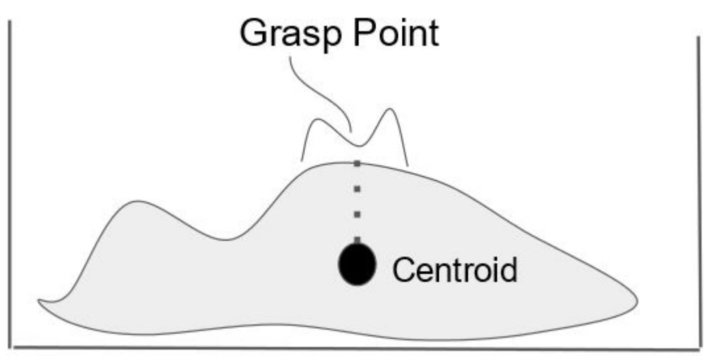

Figure 1. Example deformable item grasping point within bin.

Grasp points for rigid objects will be determined on an experimental basis. Each item will have a library of associated valid grasp points stored within the Grasping subsystem. Grasping will determine the physical locations of these grasp points within the bin geometrically, through use of the 6-DOF provided by PERCH. Each one of these grasp points will then be passed to Planning as a valid grasp surface, and Planning will then simply choose to move the arm to whichever grasp point it is able to process the soonest. An example object with three experimentally determined valid grasp points can be seen in Figure 2. In this example Grasping would pass G3 as a valid grasp point to Planning, but Planning would be unable to move to this location due to the item configuration within the bin and would instead move the end effector to G1 or G2, based off of whichever location it is able to process for sooner.

In the case that an item has multiple valid grasp surfaces, but some surfaces are more preferred than others (perhaps one surface has a sticker that has the potential to be removed, or provides a better suction surface than another, etc.), it may be worth implementing sequential requests from Grasping to Planning, in which Grasping queries Planning to the viability of particular grasping surfaces before allowing planning to choose on its own.

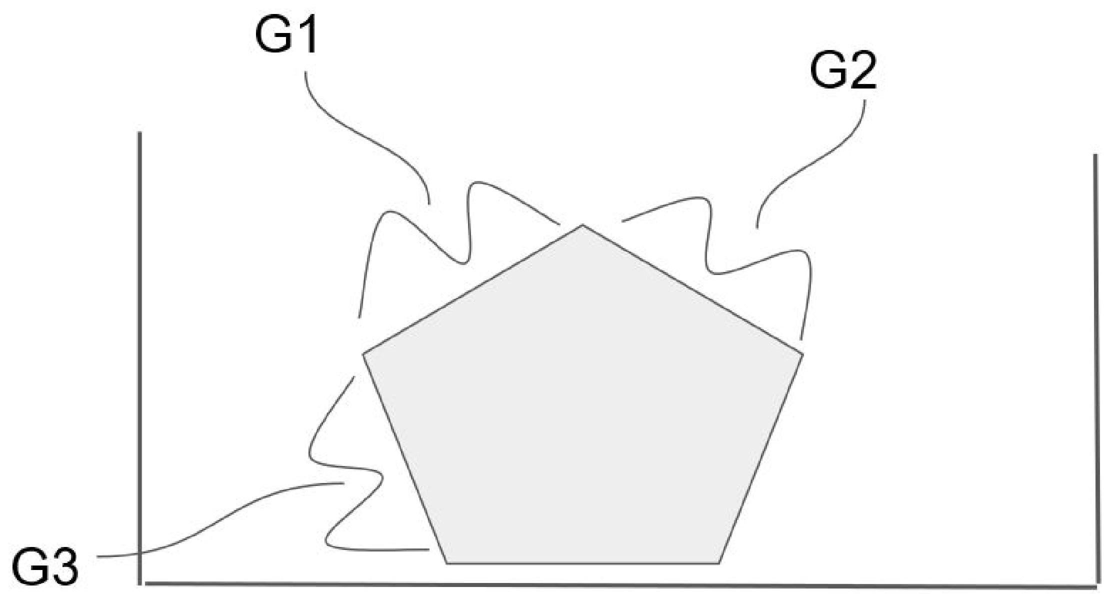

Figure 2. Example rigid item grasping points within bin.

Grasping - Gripper Hardware

Two primary gripper implementations have proven to be viable and are under consideration: suction and two-finger gripping. Suction has been the more successful of the two, allowing for quick easy grasping on roughly 90% of past challenge items. Suction has had challenges with heavier items, such as the dumbbell, and items wrapped in cellophane, such as the package of Oreo’s. Teams have utilized suction / two-finger hybrids in order to make up for these items which are challenging for suction, or have used separate arms with both styles of grippers. A suction/two-finger hybrid is ideal and is currently attempting to be implemented. Solitary suction or two-finger gripping are both still on the table however, subject to the new item list.

We have had an offer of sponsorship for two-finger gripping. Paul Ekas is the owner of SAKE Robotics and has expressed interest in working with us to use his gripper for the challenge, as seen in Figure 3.

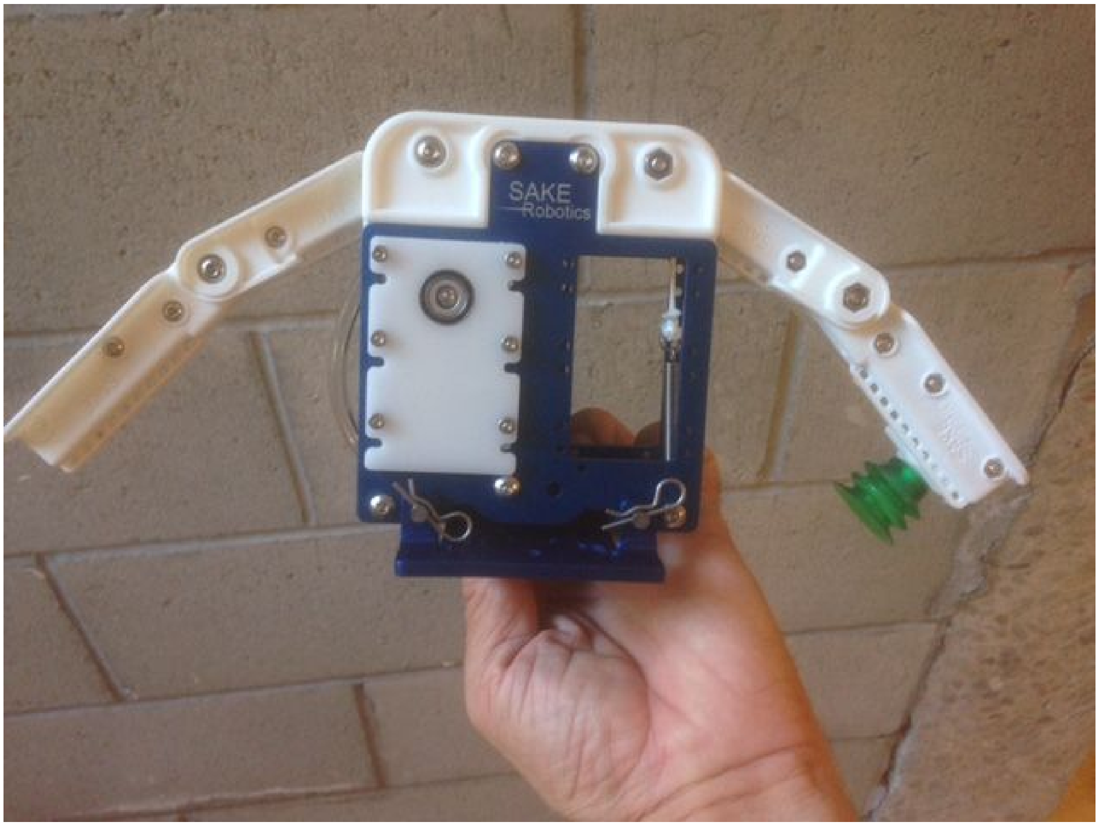

Figure 3. SAKE Robotics two-finger gripper. The suction cup is a Piab bx25p and is an optional attachment.

Specifications for the two-finger gripper as well as demonstration videos can be found here (the pliability the gripper demonstrates when grabbing the juice from the fridge is of particular note).

For suction systems we have been in contact with JJ Osmecki of Anver. JJ was sent a 2kg dumbbell and a pack of cellophane wrapped Oreo's to test with. The systems which are able to lift each item are different, as seen in Figure 4.

Figure 4. Anver suction systems for lifting the dumbbell (left) and package of Oreo's (right).

It is important to note that each system was not able to lift the other item. That is, the single large cup used to lift the dumbbell is incapable of lifting the cellophane wrapped Oreo's, and the multi-headed suction cup system which is used to lift the Oreo's is incapable of lifting the dumbbell. Images of the item lists for the last two years were sent to JJ, and his feedback was that the multi-headed suction cup system should be capable of lifting roughly 90-95% of those items.

An idealization of this feedback would be to implement the multi-headed suction cup system as a hybrid with a two-finger gripper. A further improvement would be to replace the suction cups with a soft foam that has similarly sized holes and placed channels. Foam allows for greater contouring around the item in order to create a seal, as well as providing compliance when moving the end effector onto grasping surfaces. An idealization of a foam gripper which could change states into a two-finger gripper can be seen in Figure 5.

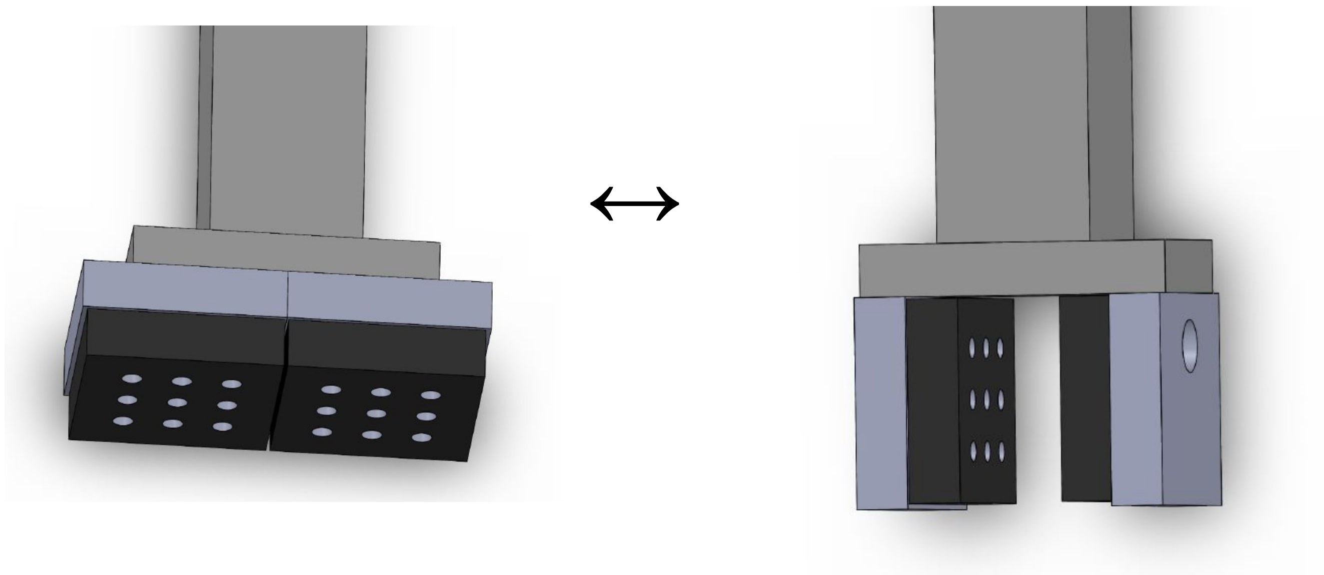

Figure 5. Gripper idealization. Gripper changes from a foam multi-channel suction head to a pliable two-finger gripper.

Shelving System

The shelving system consists of 4 drawers, which are each divided into two bins. The drawers are stacked vertically, and the second and third bins can be moved outward through the use of rollers or telescoping drawers attached to the drawers. An outside frame which is unattached to the shelf attaches and actuates in order to move the drawers into their different positions. A mockup of the shelving unit with the drawers in their initial and moved positions can be seen in Figure 6.

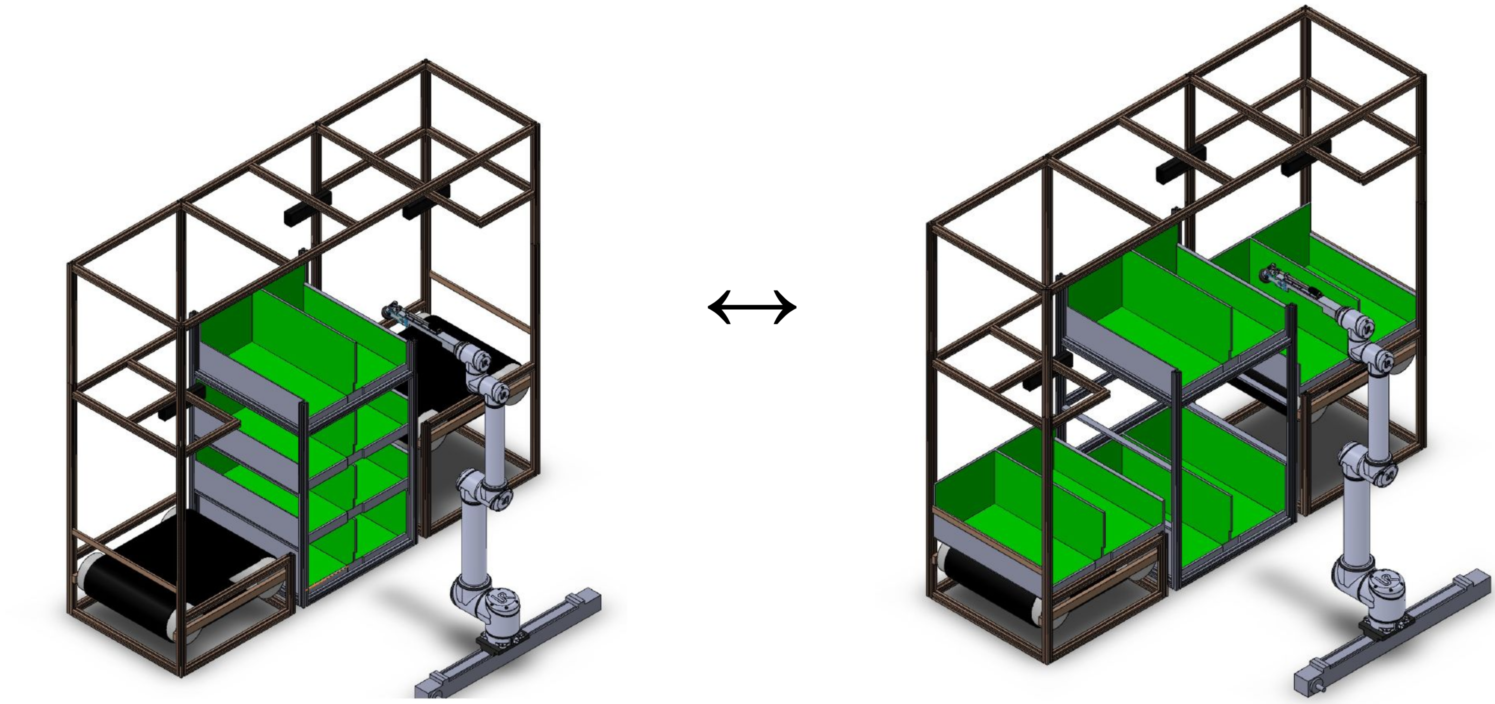

Figure 6. Shelf - actuated frame system. Shelf in initial position (left) and shelf in moved position (right).

The shelving system allows for the arm to have a top-down approach to each bin, including the bottom bin which now has an empty cavity above it where the two middle drawers originally were. The frame also provides support for static Kinects for bin image processing, as well as for any tarps or other fabric and LED strips to control system lighting.

Drawer movement will be actuated through the use of stepper motors, chains (with attachment hardware), hooks/forks, and leaf springs. The drawer will slide out on telescoping sliders attached to the shelf frame or it will move across roller casters attached to both the shelf and the actuated frame. A rough model of the drawer actuation system utilizing rollers can be seen in Figures 7 and 8.

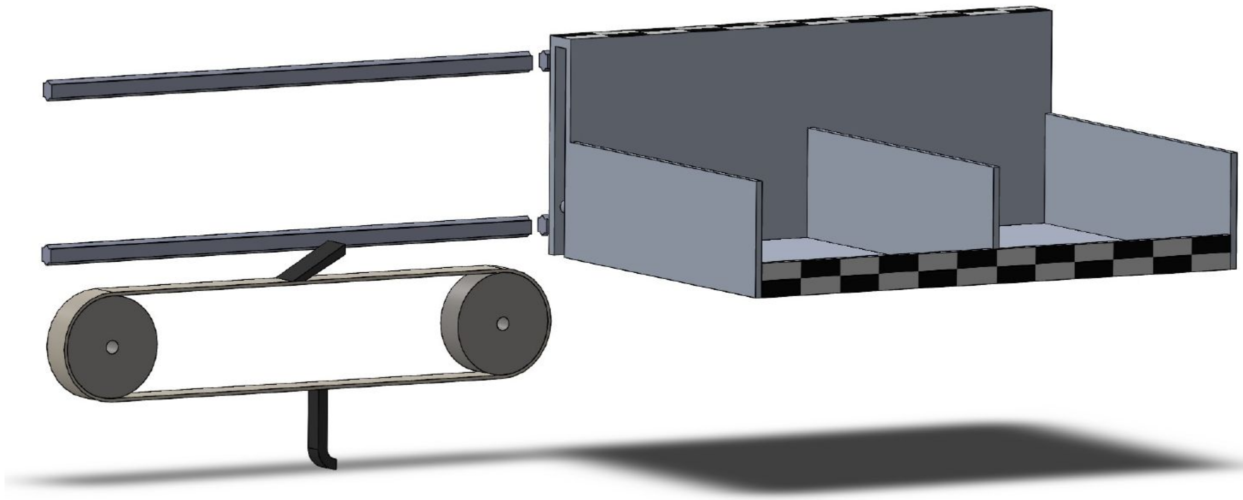

Figure 7. Drawer actuator and slider system, front view.

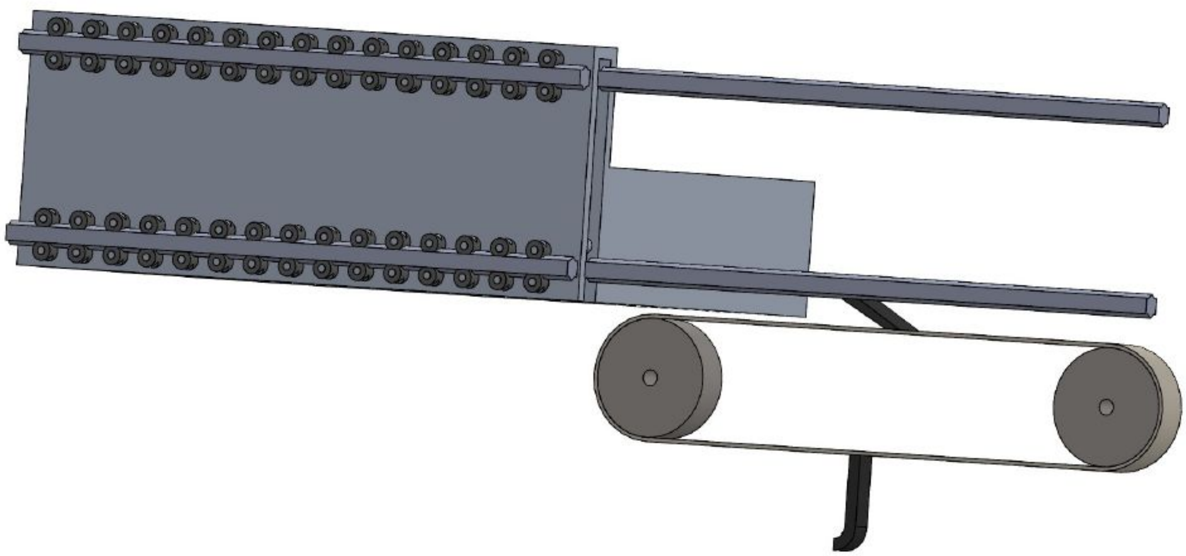

Figure 8. Drawer actuator and slider system, back view.

The sprockets will rotate the chain counter-clockwise (looking at the front view) in order to engage the hook or fork to a pin which will be fastened within the hollow portion of the drawer. As the chain continues to rotate the drawer will be pulled out. The system will rotate clockwise in order to disengage the hook, and a leaf spring opposite the hook will begin to push the drawer back into its original position. When the drawer is in its original position the leaf spring will begin to flex, allowing for some leeway in the precision of the stepper motor control.